DISTRIBUTION CHARACTERISTICS OF KRILL AGGREGATIONS IN THE FISHING GROUND OFF CORONATION ISLAND IN THE 1989/90 SEASON

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Abstract

Distributional characteristics of krill aggregations in the Coronation Island fishing ground were examined in relation to environmental factors, the biological condition of krill and the performance of the fishery. Investigations were carried out from October 1989 to February 1990. An echosounder was used to assess the characteristics of krill aggregations. Krill was harvested by standard midwater trawls with a horizontal mouth opening of 33 m. All common types of krill aggregations were recorded in the Coronation Island area over the observation period. From November to February scattered forms of krill tended to combine into larger aggregations. Wind force had no direct or indirect influence on the types of krill aggregations or their density. The increased temperature towards the end of the season, however, assisted the development of phytoplankton which in turn led to an increase in krill concentration. The biological parameters of krill examined (stages of maturity, sex ratio and krill size) varied according to aggregation type. The results obtained should be regarded as preliminary since they were based on data from one season only. Distributional characteristics of krill aggregations varied significantly over time. It was therefore recommended that CPUE simulation studies take into account the actual distributional features of targetted aggregations and the catchability rates of the trawls used at different times in the life of the fishery.

Résumé

Les caractéristiques de la répartition des concentrations de krill dans le lieu de pêche proche de l'île du Couronnement ont été examinées par rapport aux facteurs de l'environnement, à la condition biologique du krill et à la performance de la pêcherie. Les recherches ont été menées d'octobre 1989 à février 1990. Un écho-sondeur a servi à l'évaluation des caractéristiques des concentrations de krill. Le krill a été pêché par des chaluts pélagiques standard d'une ouverture horizontale de 33 m. Tous les types courants de concentrations de krill ont été signalés dans la région de l'île du Couronnement au cours de la période d'observation. De novembre à février, le krill dispersé a eu tendance à se grouper en concentrations plus larges. La vitesse du vent n'a eu aucune influence directe ou indirecte sur les types de concentrations de krill ou sur leur densité. Par contre, vers la fin de la saison, la hausse de la température a favorisé le développement du phytoplancton, ce qui a alors provoqué une augmentation des concentrations de krill. Les paramètres biologiques du krill examiné (stades de maturité, sex ratio et taille du krill) ont varié selon les type de concentrations. Les résultats obtenus devraient être considérés comme étant préliminaires, vu qu'ils sont basés sur les données d'une seule saison. Les caractéristiques de répartition des concentrations de krill ont varié considérablement au

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cours du temps. Il a de ce fait été recommandé que les études par simulation de la CPUE tiennent compte des caractéristiques mêmes de la répartition des concentrations visées et des taux de capturabilité des chaluts utilisés à différentes époques de l'historique de la pêcherie.

Резюме

Характеристики распределения агрегаций криля в промысловом районе у о. Коронейшн были рассмотрены в связи с факторами окружающей среды, биологическим состоянием криля и результатами промысла. Работы проводились в период с октября 1989 г. по февраль 1990 г. Оценка характеристик агрегаций криля проводилась с помощью эхолота. Промысел криля велся стандартным разноглубинным тралом с горизонтальным раскрытием между крыльями в 33 м. За период наблюдения в районе о. Коронейшн были зарегистрированы все известные типы агрегаций криля. С ноября по февраль была отмечена тенденция увеличения концентрации криля от разрозненных скоплений до крупных агрегаций. Сила ветра не оказывала ни прямого ни косвенного влияния на типы скоплений криля и их плотность. Однако, повышение температуры к концу сезона способствовало развитию фитопланктона и, как результат этого, повышению концентрации криля. Биологические параметры криля - стадии зрелости, соотношение полов и размер - различались в зависимости от типа концентраций. Полученные выводы следует считать предварительными, поскольку они были получены на материалах только одного сезона. Характеристики распределения агрегаций криля на промысловом участке существенно менялись во времени. В результате этого было рекомендовано при расчете величины CPUE методом математического моделирования принимать во внимание реальные характеристики распределения криля в облавливаемых агрегациях и уловистость используемых тралов в различные периоды промысла.

Resumen

Se estudian las características de distribución de las concentraciones de krill en los caladeros de la isla Coronación en relación a los factores del entorno físico, la condición biológica del krill y la actuación de la pesquería. Los trabajos de investigación se llevaron a cabo desde octubre 1989 a febrero 1990; empleándose un ecosondas para evaluar las características de las concentraciones. Las pescas de krill se realizaron con un arrastre pelágico estándar cuya abertura horizontal de la boca era de 33 m. Durante el período de observación de la zona de la isla Coronación, se registraron todos los tipos comunes de concentración. De noviembre a febrero las formaciones dispersas de krill tendían a formar agrupaciones más amplias. La fuerza del viento no influyó en la forma de las concentraciones ni en su densidad. Sin embargo, el aumento de la temperatura hacia el final de la temporada provocó la formación de fitoplancton lo que a su vez originó el crecimiento de la concentración de krill. Los parámetros biológicos

del krill examinados (fases de madurez, proporción de sexo y tallas) variaron según el tipo de concentración. Los resultados obtenidos deben considerarse preliminares ya que se han basado únicamente en los datos de una sola temporada. Las características de distribución de las concentraciones de krill variaron considerablemente según la época. Se recomienda por lo tanto que los estudios de simulación de la CPUE tengan en cuenta las características reales de distribución de las concentraciones escogidas, así como los índices de capturabilidad de los arrastres utilizados en las distintas épocas de la pesquería.

1. INTRODUCTION

The characteristics of krill distribution have been the subject of a series of scientific works (Kalinowski and Witek 1982, 1985; Anon., 1986; Godlewska and Kluzek, 1988; Miller and Hampton, 1989; William and Hamner, 1984).

The data used in most of these papers have been obtained as a result of scientific programs such as FIBEX and BIOMASS. The study of krill CPUE also requires knowledge of its distributional characteristics in fishing grounds (Endo and Ichii, 1989). These characteristics are determined by environmental factors as well as the biological condition of krill.

The authors have attempted to examine changes in distributional characteristics of krill aggregations in fishing grounds as they relate to krill biology and the performance of the fishery.

2. MATERIALS AND METHODS

Investigations were carried out on board a fishing vessel which did not have echo-integrating equipment, a fact which severely limited the amount of hydroacoustic information obtained. Distributional characteristics of krill aggregations were assessed on the basis of echogram recordings according to a methodology developed by AtlantNIRO (1985).

Since a hydroacoustic assessment of the effectiveness of the midwater trawl type 74/416 used for taking krill was not carried out, catchability was calculated on the basis of statistical probability models used for fishing trawls. This method is quite accurate when used to assess trawl catchability and is an acceptable alternative to hydroacoustic methods (Kasatkina, 1989; Kadilnikov *et al.*). Maximum krill speed in the calculations was taken to be $\mathbf{V}_{max}$=0.23 m/s (Kasatkina and Myskov, 1986; Hamner, 1984). Trawl specifications for the type 74/416 are given in Table 1.

CPUE (Catch-per-unit-effort) was assessed as catch per hour of trawling because expended fishing effort can be expressed as trawling time for a standard trawl. Since we are examining the performance of a single vessel, the 74/416 type trawl is taken as standard.

A well-grounded estimate of mean catch per hour of trawling, **Q/hr**, (Ivanova, 1988; Smith, 1980) was calculated in the following manner:

$$\bar{m}(Q/hr) = \frac{\sum_{i=1}^{n} Q_i}{\sum_{i=1}^{n} T_{tp.i}}$$

where Q_i = catch in haul i;
$T_{tp.i}$ = duration of haul i;
n = number of hauls over the study period.

Relative error of mean catch per hour of trawling is

$$\xi\,(\bar{m}Q/hr) = \pm\frac{t_\varepsilon}{\sqrt{n}}\left(\frac{\sigma_Q}{\bar{m}_Q} + \frac{\sigma_t}{\bar{m}_t}\right)$$

where t_e = confidence coefficient according to confidence probability ε;
σ_Q = standard deviation of catch per haul;
$\bar{m}_Q$ = mathematical expectation of catch per haul;
σ_t = standard deviation of the duration of one haul;
$\bar{m}_t$ = mathematical expectation of the duration of one haul.

Krill biological condition was determined according to "Methodical Instructions on Sampling and Primary Treatment of Biological Material and Data on Antarctic Krill *in situ*" (Moscow, VNIRO, 1982).

Sea surface temperature was measured to within 0.2°C of accuracy.

3. RESULTS

The entire period of investigations (18 November 1989 to 27 February 1990) may be divided into six smaller periods during which fairly similar krill aggregations were recorded.

The distribution of krill and the catchability coefficient of the 74/416 midwater trawl were evaluated for each of these time intervals (Table 2). Data on catch per hour trawling are given in Table 3; daily catch and fishing effort expended are shown in Table 4.

(Period I) 18 November to 3 December 1989

Observations were carried out over two fishing grounds during this period: north-east (50°10'S to 59°30'S and 43°30'W to 44°W) and south-west (Figure 1).

In the daytime, krill was recorded as a scattered layer in the 10 to 140 m depth range with interrupted, short tracks formed by poorly defined swarms. In periods of darkness (between dusk and dawn), krill was located above depths of 40 m, forming a dispersed sub-surface layer. Daily vertical migration was indistinct (Figure 2).

Mean catch per hour of trawling was $\bar{m}(Q/hr) = 2.15$ tonnes (Table 3). Commercial catches ($\bar{m}(Q/hr) = 13.4$ tonnes, $\sigma_Q = 6$ tonnes) were obtained due to prolonged periods of trawling: $\bar{m}_t = 5.8$ hrs, $\sigma_t = 2.5$ hours.

Wind force over this period dropped from 3.5 to 2 on the Richter scale while water temperature was between 0° and 0.5° (Figure 4a).

In the north-east fishing ground, mean krill length was 47.8 mm and 45.4 mm in the south-west. The sex-ratio was 0.67 for males and 1.08 for females. A sharp drop in the proportion of post-spawning males and a significant increase in the number of females with a normal thorax were noted in the south-west towards the end of the study period (Figures 3b and 3c). The maturity stages of female ovaries were from 1 to 3 (Figure 3g) and 60% of females had spermatophores. Krill feeding intensity increased somewhat throughout the study period (Figure 3e).

(Period II) 4 December to 18 December 1989

The fishing ground was located to the north-west of Coronation Island (Figure 1).

Krill aggregations were recorded as fields of swarms dispersed in the depth layer of approximately 70 m. Towards nightfall these swarms ascended to the surface and dispersed, forming a rather uniform and sparse layer or separate sparse patches after 11 p.m. Swarming occurred with the onset of dawn (2:30 to 3:00 a.m.) and after five a.m. these swarms migrated downwards (Figure 2b).

Mean catch per hour of trawling was $\bar{m}(Q/hr) = 3.9$ tonnes (Table 3). Catchability coefficient when targetting such aggregations was calculated to be $P = 0.0605$ (see Table 2).

It should be noted that a temporary redistribution of krill took place from 7 to 8 December. In daylight hours, krill adhered to depths less than 90 m and formed swarms of higher density:

$$\lambda_s = 1.38.10^{-4}\ m^{-2},\ \beta = 0.2089.$$

Catchability coefficient was calculated at $P = 0.116$. Catch per hour of trawling increased to $\bar{m}(Q/hr) = 7.5$ tonnes. Catch per haul was $\bar{m}(Q) = 24.7$ tonnes; $\sigma_Q = 5.4$ tonnes and trawling duration: $\bar{m}_t = 3.3$ hours, $\sigma_t = 1.0$ hrs. Wind force rose to 4 and temperature dropped to below 0°C towards the end of the period (Figure 3a).

In Period II, mean krill length was from 44 to 47 mm and the sex-ratio of males and females was 0.99. The proportion of post-spawning males notably increased due to those maturing for the first and repeat times and also specimens at the "rest" stage (Figure 3b). A rise in the number of females with enlarged thoraxes due to maturation of eggs was observed. Krill feeding intensity reached its highest level (Figure 3d). Up to 80% of females had spermatophores.

The temporary redistribution of krill on 8 December, which changed the nature of the aggregation, coincides with a transition period in mating and feeding (see Figures 3b and 3f from 1-7 December to 8-15 December 1989).

(Period III) 9 December 1989 to 7 January 1990

The fishing ground shifted somewhat towards the west (Figure 1). Swarms were distributed over a wide range of depths and vertical migration was quite distinct (Figure 4). At night-time (23:00 to 2:00), krill formed sub-surface, sparse patches. In daylight hours column-shaped swarms having a vertical extent of up to 70 m were recorded.

Tables 2 and 3 show that the density of the targetted concentration was somewhat lower compared to the previous period. However, due to the increased catchability of the trawl, the value $\bar{\mathbf{m}}(\mathbf{Q/hr})$ practically remained the same and was equal to 3.99 tonnes.

Wind force for this period decreased to 2-3 on the Richter scale while water temperature ranged from 0° to +0.7°C (Figure 3a).

Mean length of krill in catches was 47.7 mm and the sex-ratio of males and females was 0.99. There was a continued increase in the proportion of mature males as well as females with an enlarged thorax (Figures 3b and 3c). Mature females were not encountered. Towards the end of the period, feeding intensity decreased notably judging by the drop in the proportion of specimens with dark and dark green livers. About 100% of females had spermatophores.

(Period IV) 8 to 28 January 1990

The fishing ground shifted somewhat to the south-east (Figure 5). Targetted krill swarms were recorded as "tracks" with clearly defined daily vertical migration. At night-time (from 0 to 2:30) krill formed a sub-surface, scattered layer. The formation of "tracks", which during daylight hours adhered to the 50 to 110 mm layer (Figure 6a), began as dawn approached.

Krill density was low with the average being $\boldsymbol{p_v}$ = 2.21 g/m^3. However, due to the increase in trawling duration ($\bar{\mathbf{m}}_t$ = 4 hrs) and the relatively high catchability of the trawl ($\mathbf{P}$ = 0.1252), commercial catches were taken ($\bar{\mathbf{m}}(\mathbf{Q})$ = 15.9 tonnes σ_Q = 5.5 tonnes). Moreover, catch per hour of trawling was the same as before, being on average 3.98 tonnes (Tables 2 and 3).

Wind force for the period increased from 2 to 4 on the Richter scale and temperature rose from 0.7° to 1.2°C (Figure 3a).

Mean krill length increased to 49 mm and the sex ratio was 2.05.

Male sexual maturity was virtually the same (Figure 3b), although females underwent some significant physical changes (Figures 3b and 3g). Female gonads fully matured and spawning was able to take place. Feeding intensity reached its maximum level in this period (Figure 3e) and catches per hour trawling increased (Figure 3a).

(Period V) 29 January to 18 February 1990

Fishing grounds were the same as for the previous period (Figure 5).

Targetted aggregations were formed from large swarms (Table 2). In the daylight hours swarms turned into large irregularly shaped patches or dense, extended layers. At night-time, concentrations remained at depths of less than 40 m where krill formed a sub-surface, dense layer from smaller swarms or sparse patches. Daily vertical migration was clearly defined (Figure 6b).

Catch per hour of trawling was $\bar{m}(Q/hr) = 6.2$ tonnes, while catch per haul was $\bar{m}(Q) = 19.6$ tonnes.

Mean krill length increased to 50 mm and the sex ratio of males and females was 1.08.

Wind force reached 3 on the Richter scale and water temperature dropped to 0.7°C (Figure 3a). The proportion of post-spawning males decreased due to their entering the "rest" stage (Stage II). The number of females with hypertrophied thoraxes as well as those bearing eggs decreased notably (Figures 3c and 3d) while feeding intensity increased slightly. Catches per hour trawling on average increased (Figure 3a).

(Period VI) 19 to 27 February 1990

The fishing ground was the same as previously (Figure 5). During the day, swarms with varying density field λ_σ formed aggregations. It was observed that adjacent swarms formed concentrations. At night-time, the distributional pattern of krill was practically unchanged in comparison with the previous Period V.

High density (p_v = 12.2 g/m^3) and a high trawl catchability rate (**P** = 0.101) enabled large catches ($\bar{m}(Q)$ = 18.1 tonnes) to be taken when trawling duration was relatively short. Catches per hour trawling were $\bar{m}(Q/hr)$ = 12.2 tonnes.

Daily vertical migration of krill was down when compared with the previous period (Figure 7). Wind force increased to 3.5 and the temperature rose to 1.5°C. Catches per hour trawling reached their maximum levels (Figure 3a). The proportion of males entering the "rest" reproductive period also increased (Figure 3b). Almost all females spawned. Sex ratio was 1.08. Mean krill length was 49.8 mm.

4. DISCUSSION

Over the observation period from November 1989 to February 1990, all types of krill aggregations were recorded at the fishing grounds around Coronation Island in accordance with an established classification system (Kalinowski and Witek, 1985):

- scattered forms (Period I);
- swarms and irregular forms in daylight hours and scattered forms at night-time (Periods II and III);
- layers in daylight hours and scattered forms at night-time (Period IV);
- irregular forms in daylight hours and scattered forms at night-time (Period V); and
- fields of swarms in the daytime and scattered irregular forms at night-time (Period VI).

The tendency of krill aggregations to change from scattered krill to swarm field was established on the basis of data from hydroacoustic surveys conducted in the South Orkney area in the period from November 1989 to February 1990 and also from other years, e.g. November 1984 to February 1985 (Kasatkina, 1987). Table 4 shows how the mean daily krill catch over various periods varied from 35 to 46 tonnes.

With the variation in distribution of targetted krill aggregations there also occurred significant changes in catch-per-unit-effort and the catchability rate (Tables 2 and 3). For example, the spatial redistribution of krill from scattered aggregations (Period I) to dense fields of swarms (Period VI) together with increased biomass density (concentrations) and trawl catchability made it possible to obtain practically an identical mean daily catch even though almost five times less fishing effort was expended.

The results of our studies agree well with data from earlier hydroacoustic assessments of fishing gear catchability in relation to krill (Kadilnikov *et al.*, 1989). The latest assessments demonstrated that the midwater trawl catchability coefficient is a random value and is the function of behavioural and distributional characteristics of the target species and the specifications and structural elements of the trawl. Catch-per-unit-effort depends on the aggregation density of the target species and the catchability of the trawl.

A comparative analyses of the dynamics of change in distributional characteristics of krill aggregations with environmental conditions and krill's biological condition allows us to draw the following preliminary conclusion.

Wind force appeared to be normal (2 to 4) and apparently had neither direct nor indirect effect on the type of aggregations formed and their density.

Water temperature had no direct impact on krill distribution, although increased temperature towards the end of the observation period raised the temperature gradient of the thermocline which improves conditions for phytoplankton (Latogursky *et al.*, 1972). This in turn leads to an increase in swarm density.

Low catches and scatterred swarms in Period I were paralleled by the greatest number of mating males, the least number of mature females and the lowest levels of feeding intensity. It should therefore be supposed that intense mating behaviour and low levels of feeding activity compelled krill to become more mobile, thus determining aggregation type and density. As a consequence the fishery was quite successful.

The change in swarm type and the increase in catches in Period II was linked to a decrease in krill mobility which was determined by a sharp drop in reproductive activity and improved feeding conditions.

The formation of the above type of aggregations and the decrease in swarm density in Period III may be primarily the result of a temporary worsening of feeding conditions and the sharp reduction in the number of females with an enlarged thorax due to egg maturation. It is known that a deterioration of feeding conditions leads to krill being scattered (Latogursky, 1972). Moreover, sexual maturation of females at different times means that they will descend to deeper waters to spawn at different times. This leads to an increase in the vertical extent of swarms, i.e., a decrease in density.

The fourth observation period witnessed an acute rise in surface water temperature, a much larger proportion of spawning females, a predominance of males over females by two to one and also the beginning of spawning. The increase in krill mean length to 49 mm and the increase in the number of spawning females should have significantly increased krill biomass on the fishing ground. Despite some negative factors, such as the increase in the number of males in catches (they are more mobile than females), the overall result was nevertheless positive and catches started to increase towards the end of this period.

In Period V the proportion of post-spawning males and females grew against a background of continued increased feeding activity and larger krill size. This facilitated the increase in aggregation density, krill biomass and, consequently, catch-per-unit-effort.

The type of aggregations observed in Period VI may be linked to the continued increase in the proportion of males and females feeding intensely who went into the "rest" reproductive stage (Stage II in males, non-enlarged thorax in females). This evidently enabled males and females of the same size groups to form separate swarms.

5. CONCLUSIONS

It may be concluded that in general a relationship exists between types of aggregations and the biological condition of krill within those aggregations. However, the results obtained should be regarded as preliminary since only data from one season have been examined.

Distributional characteristics of krill swarms change markedly over time in the fishing ground. This factor varies the catchability of the midwater trawl and affects the size of the catch-per-unit-effort. Therefore, when estimating CPUE using modelling it is essential, in our opinion, to examine the real distributional characteristics of krill in targetted aggregations and the catchability coefficients of the midwater trawls used during various periods of the fishery.

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Table 1: Specifications for trawl type 74/416.

Element	Value
Vertical opening in the trawl bag	42 m
Vertical opening of fine-meshed insertion	9.5 m
Horizontal opening of fine-meshed insertion	9.5 m
Horizontal opening between doors	56 m
Horizontal opening between trawl wings	33 m
Trawl length along shift from wing tips to fine-meshed insertion	141 m
Length of cable with tow legs	100 m
Trawling speed	3.0 to 3.3 knots
Length of trawl board	4 m
Mesh bar of bag netting	12 mm

Table 2: Mean values of krill distribution parameters and catchability of the 74/416 trawl in the fishing grounds off Coronation Island.

Parameter	Periods					
	18 November to 3 December 1989	4 December to 18 December 1989	19 December 1989 to 7 January 1990	8 January to 28 January 1990	29 January to 18 February 1990	19 February to 27 February 1990
Swarm distribution - mean layer depth (m)		100	95	100	77	70
Mean vertical extent of swarms (m)		15	18	5	17	19
Standard deviation of vertical extent of swarms (m)		4	7	2	6	8
Mean horizontal length of swarms (m)		72	89	28	89	75
Standard deviation of horizontal extent of swarms (m)		21	25	12	23	18
Mean swarm diameter (m) [it is assumed that swarms are of a cyclindrical shape]		92	120	36	120	84
Mean swarm volume (m^3)		9.97×10^4	2.03×10^5	5.09×10^3	1.92×10^5	1.05×10^5
Relative density of swarms in 3-dimensional space, β		0.0298	0.0982	0.2796	0.188	0.168
Density of a field of swarms in 2-dimensional space λ_s		2.98×10^{-5}	4.78×10^{-5}	5.4×10^{-3}	7.52×10^{-5}	1.11×10^{-5}
Mean krill density p_V,g/m^3 (calculated estimate)		4.49	4.07	2.20	5.88	9.46
Calculated estimate of total catchability of a 74/416 trawl		0.0605	0.068	0.1253	0.0807	1.101

Table 3: Results of targetting krill aggregations off Coronation Island.

Parameter	Periods					
	18 November to 3 December 1989	4 December to 18 December 1989	19 December 1989 to 7 January 1990	8 January to 28 January 1990	29 January to 18 February 1990	19 February to 27 February 1990
Mean catch per haul (tonnes)	13.4	15.1	13.3	15.9	19.6	18.1
Standard deviation of catch per haul (tonnes)	6.6	5.8	5.3	6.5	5.4	5.7
Mean trawling duration (hrs)	5.8	3.8	3.3	4.0	3.2	1.4
Standard deviation of hauling duration (hrs)	2.5	1.5	1.3	2.5	1.0	0.6
Mean catch per hour trawling (tonnes)	2.15	3.93	3.99	3.98	6.22	12.2
Relative error of mean catch per hour of trawling	0.21	0.209	0.195	0.157	0.138	0.277

Table 4: Daily krill catch and expended fishing effort.

Parameter	Periods					
	18 November to 3 December 1989	4 December to 18 December 1989	19 December 1989 to 7 January 1990	8 January to 28 January 1990	29 January to 18 February 1990	19 February to 27 February 1990
Mean daily catch (tonnes)	34.8	35	35	44.0	46.1	37.8
Standard deviation of daily catch	19.1	13.2	13.2	18.1	12.7	11.9
Mean fishing effort expended over 24 hours (hrs)	15.6	10.7	8.8	11.2	7.4	3.1
Standard deviation of mean fishing ffort expended over 24 hours (hrs)	6.5	4.1	3.4	3.5	2.9	1.4

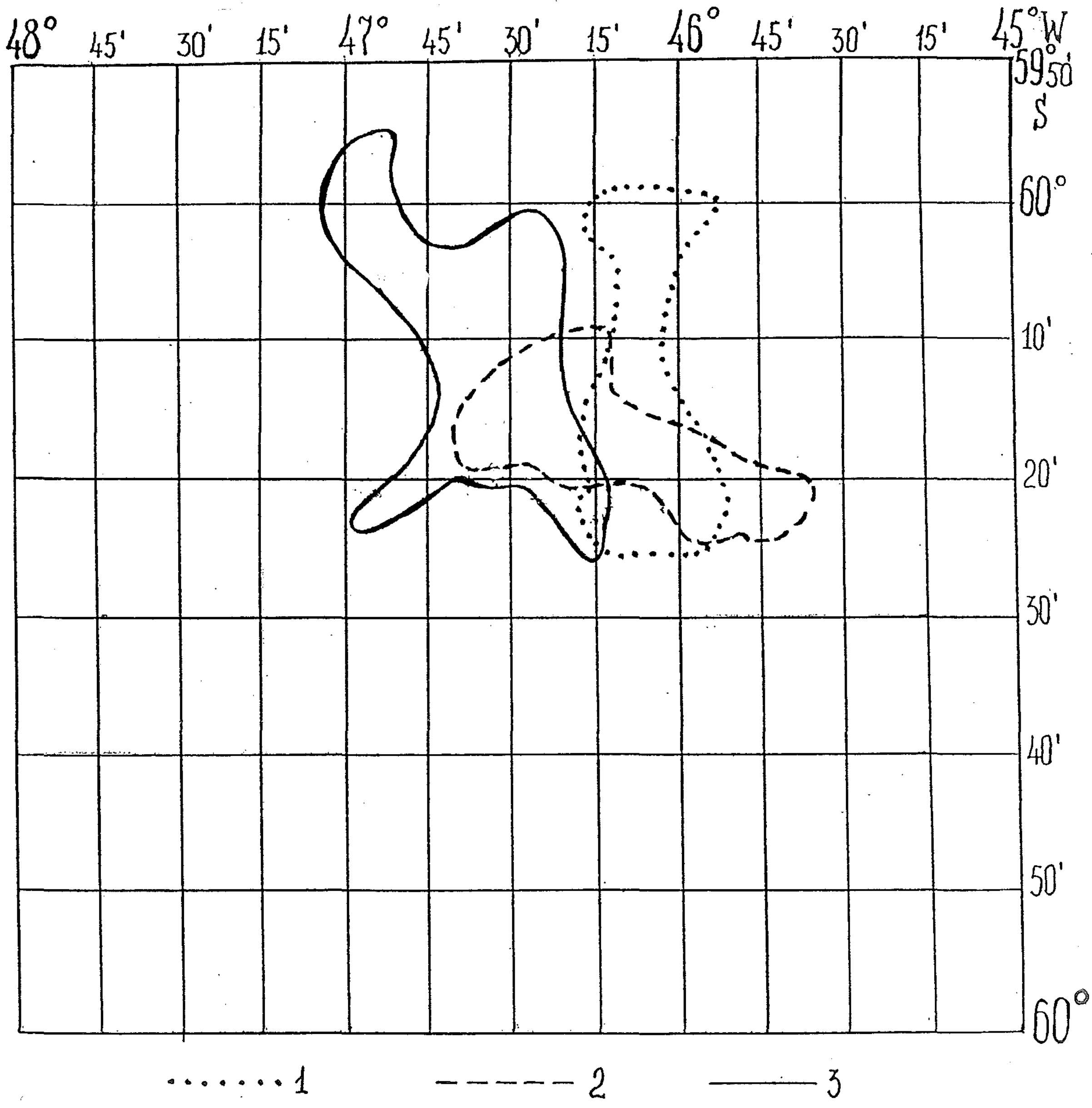

Figure 1: Fishing grounds in the Coronation Island area from 18 November 1989 to 7 January 1990.
Period I: 18 November to 3 December
Period II: 4 to 18 December
Period III: 19 December to 7 January.

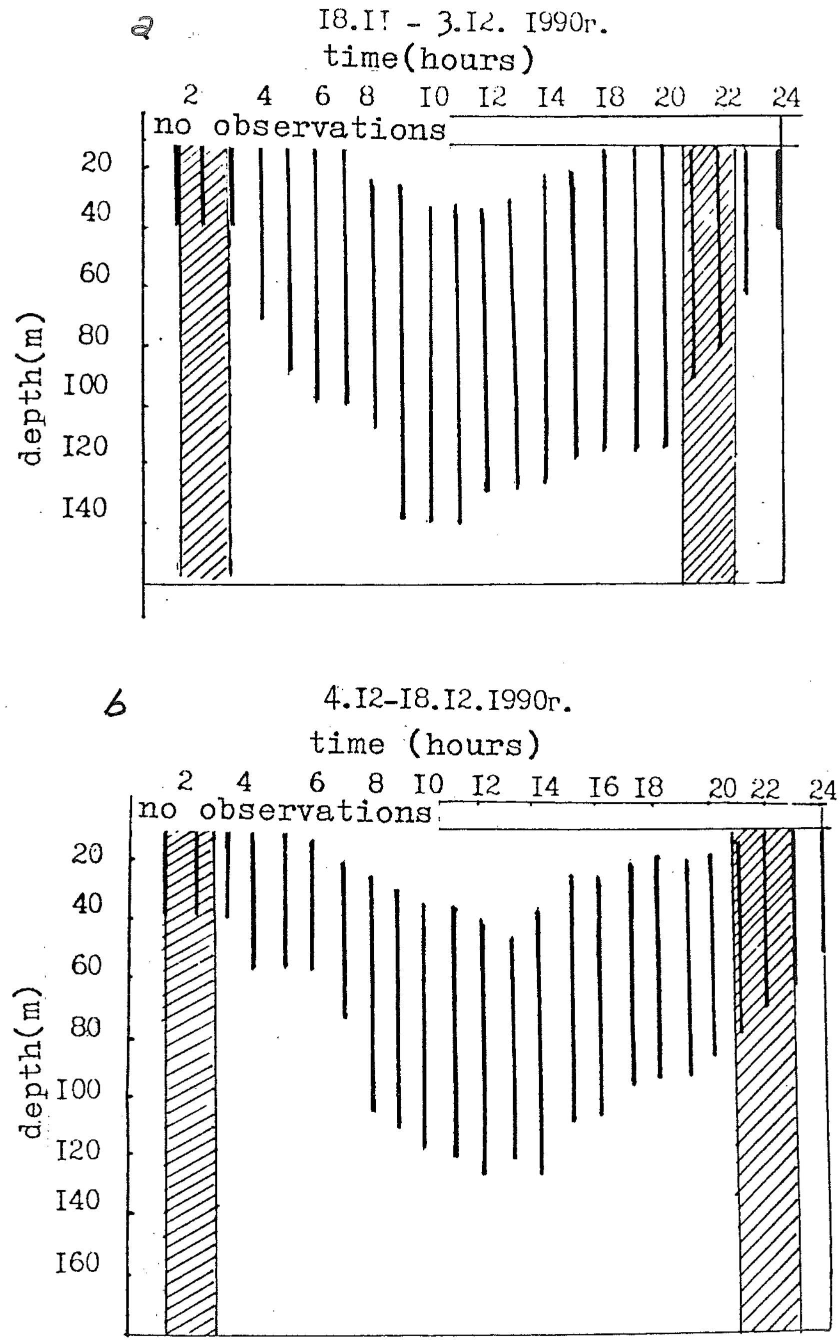

Figure 2: Daily vertical distribution of krill.
(a) from 18 November to 3 December 1989
(b) 4 to 18 December 1989
Shaded area represents dawn and dusk

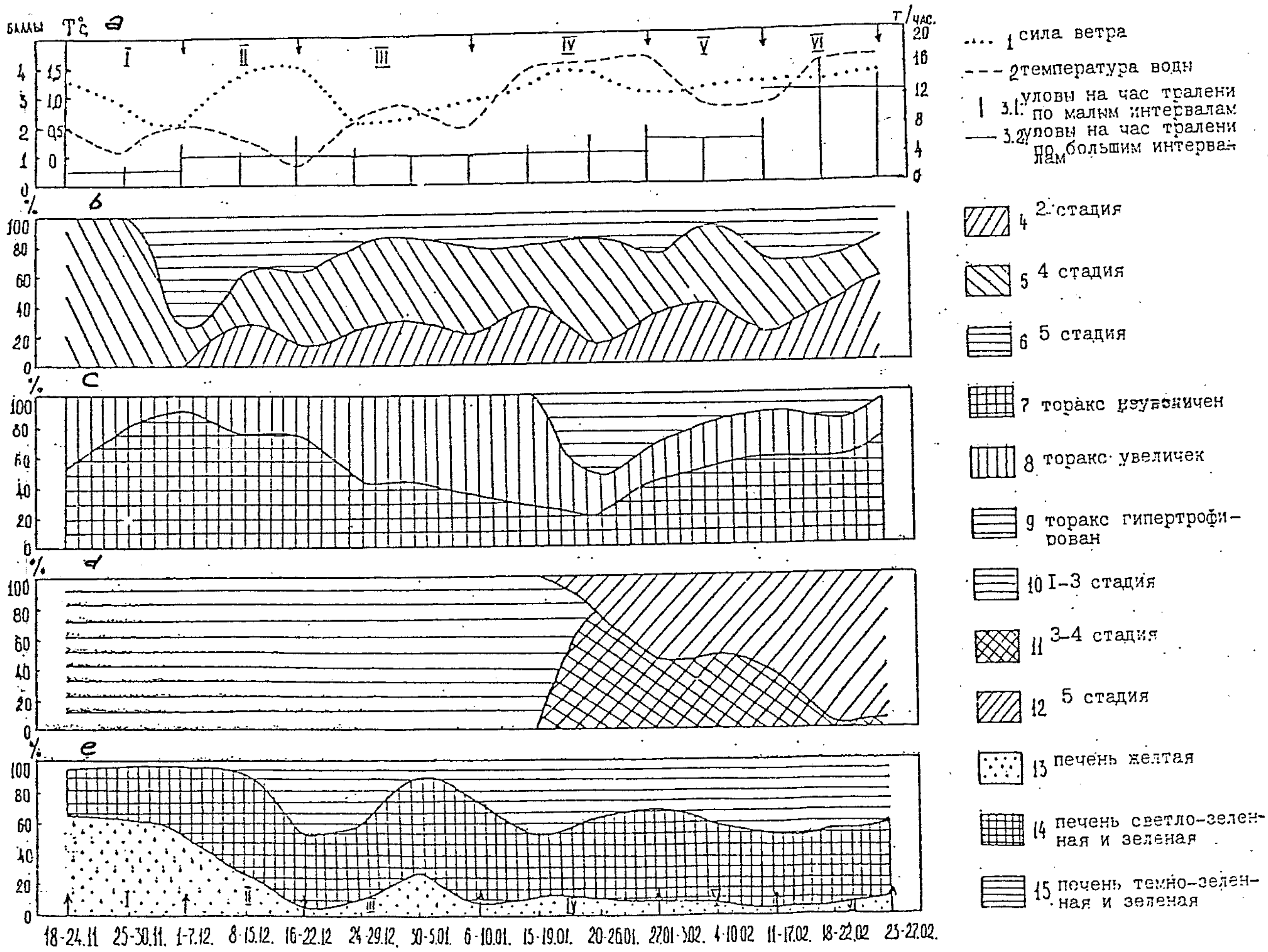

Figure 3: Wind force, water temperature in the 5 to 6 m layer.
(a) catches per hour of trawling; (b) male maturity stages; (c) female thorax condition; (d) female maturity stages; (e) krill feeding intensity.

1 - wind force
2 - water temperature
3.1 - catches per hour of trawling over short intervals
3.2 - catches per hour of trawling over long intervals
4 - Stage II
5 - Stage IV
6 - Stage V
7 - thorax not enlarged
8 - thorax enlarged
9 - hypertrophied thorax
10 - Stages I-III
11 - Stages III-IV
12 - Stage V
13 - liver yellow
14 - light-green/green liver
15 - dark-green/green liver

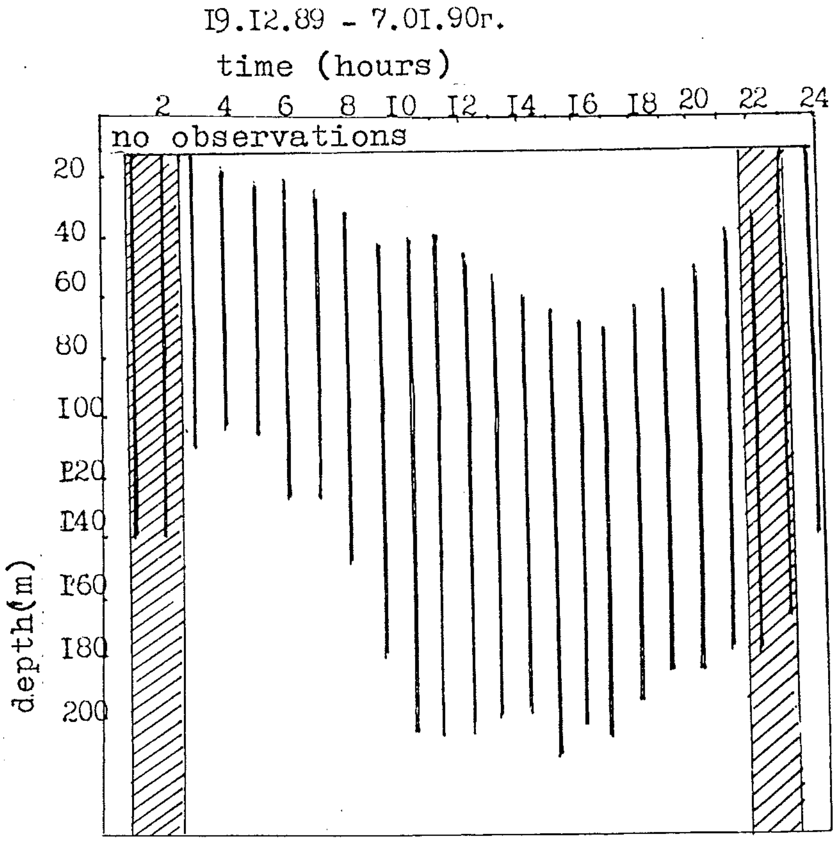

Figure 4: Daily vertical distribution in the fishing ground off Coronation Island, 19 December 1989 to 7 January 1990.

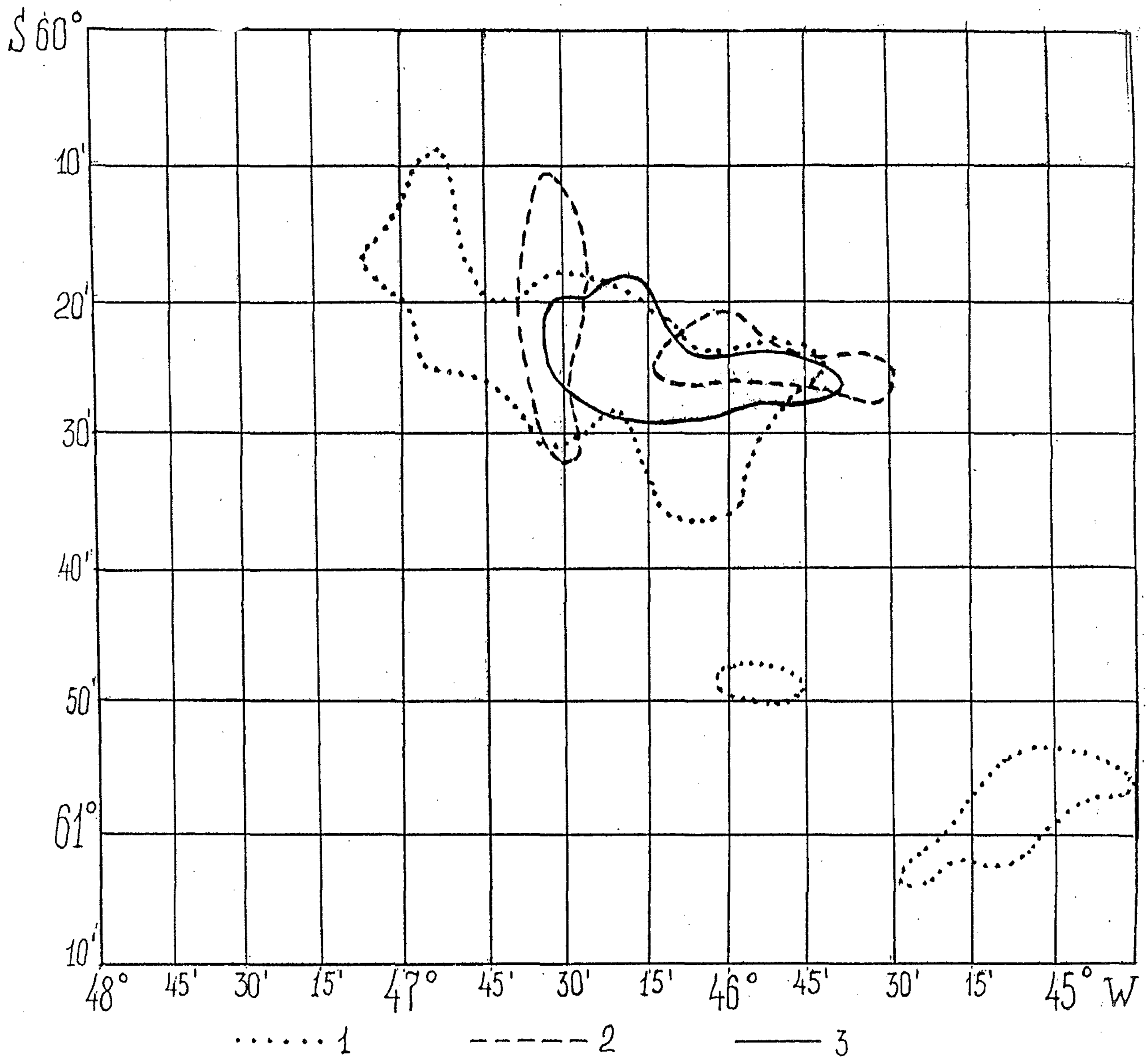

Figure 5: Fishing grounds off Coronation Island, 8 January to 27 February 1990.
Period I: 8 to 28 January
Period II: 29 January to 18 February
Period III: 19 to 27 February

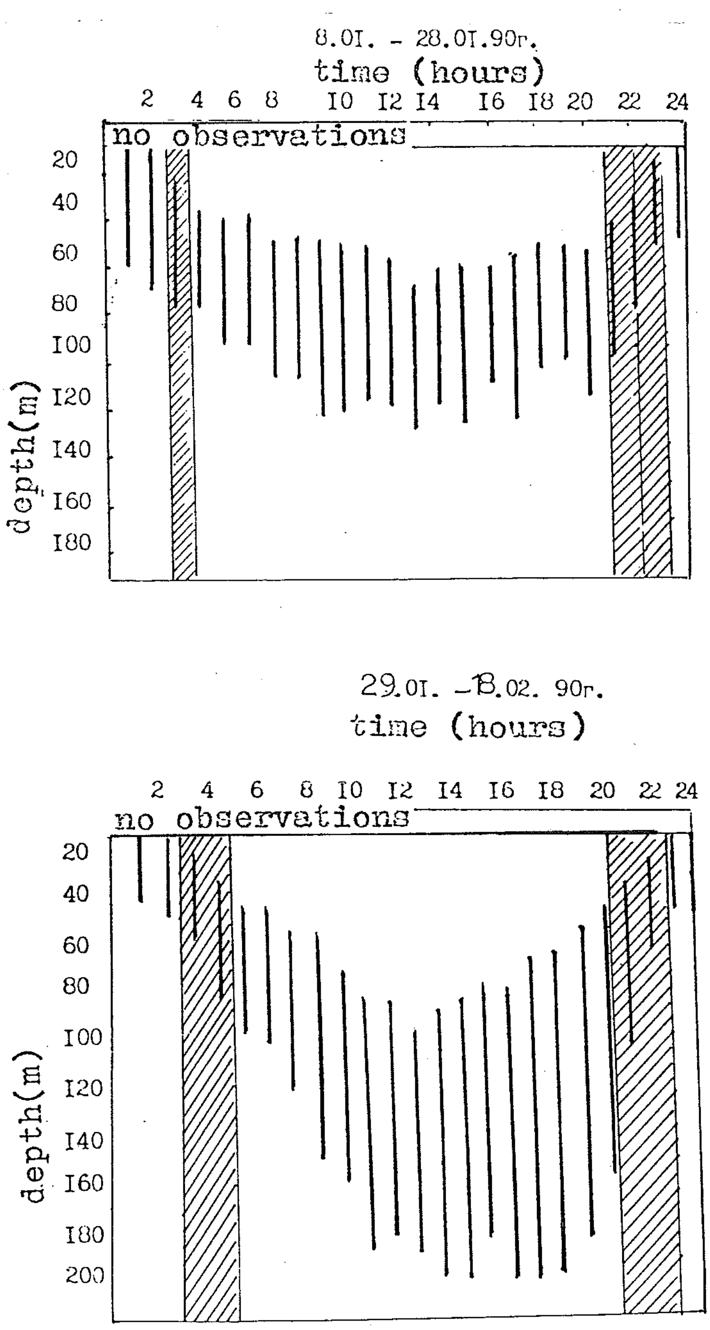

Figure 6: Daily vertical distribution of krill.
(a) 8 to 28 January 1990
(b) 29 January to 18 February 1990
Shaded area represents dawn and dusk

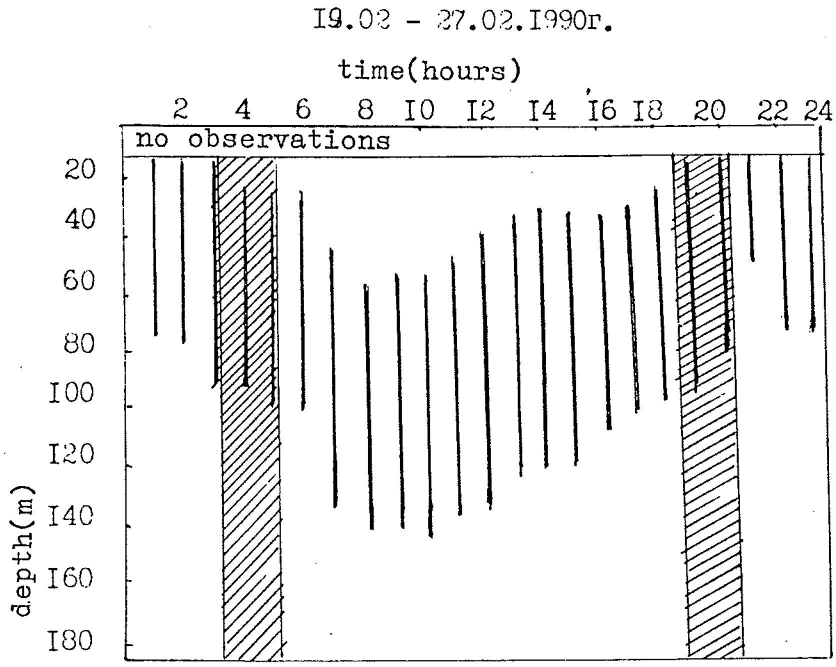

Figure 7: Daily vertical krill distribution in the fishing ground off Coronation Island, 19 to 27 February 1990.

Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Рисунок 4: Суточное вертикальное распределение на промысловом участке в районе острова Коронейшн, 19 декабря 1989 г. - 7 января 1990 г.

Рисунок 5: Промысловые участки в районе острова Коронейшн, 8 января - 27февраля 1990 г.
Период I: 8-28 января
Период II: 29 января - 18 февраля
Период III: 19-27 февраля

Рисунок 6: Суточное вертикальное распределение криля.
(a) 8-28 января 1990 г.
(b) 29 января - 18 февраля 1990 г.
Периоды рассвета и сумерек обозначены штриховкой

Рисунок 7: Суточное вертикальное распределение криля на промысловом участке в районе острова Коронейшн, 19-27 февраля 1990 г.

Lista de las tablas

Lista de las figuras

8 - tórax aumentado.
9 - tórax hiperatrofiado.
10 - fase I - III.
11 - fase III - IV.
12 - fase V.
13 - hígado amarillo.
14 - hígado verde y verde claro.
15 - hígado verde y verde oscuro.

Figura 4: Distribución vertical diaria del krill en el caladero de pesca de la isla Coronación, del 19 de diciembre 1989 al 7 de enero 1990.

Figura 5: Caladeros de pesca de la isla Coronación, del 8 de enero al 27 de febrero 1990.
Período I: 8 al 28 de enero.
Período II: 29 de enero al 18 de febrero.
Período III: 19 al 27 de febrero.

Figura 6: Distribución vertical diaria del krill.
(a) 8 al 28 de enero 1990
(b) 29 de enero al 18 de febrero 1990
Las zonas oscuras corresponden a las horas del crepúsculo.

Figura 7: Distribución vertical diaria del krill. Caladeros de pesca de la isla Coronación, del 19 al 27 de febrero de 1990.